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VHDL Simulation of Tu-11/Tu-12 in Synchronous Digital Hierarchy

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Abstract: - ***One of important transmission technologies in the broadband ISDN is the synchronous transmission technology based on SDH, a key concept of SONET/SDH is the pointer-based access to the encapsulated payloads in the SONET/SDH signal. The Synchronous Digital Hierarchy (SDH) and the Synchronous Optical NETwork (SONET) are hierarchies used in Europe/South-America and North-America/Japan, respectively. Both systems employ synchronous time division multiplexing techniques to transmit different tributaries (EI, Ethernet, ATM, etc) through the same physical channel. A primary goal in the development of the SDH/SONET formats is to define a synchronous optical hierarchy with sufficient flexibility to carry payloads of different types. SONET and SDH are based on transmission at rates that are integer multiples of 51.840 Mbps. SONET basic frame structure is called synchronous transport signal level one (STS-l). SDH basic modular signal is called synchronous transport module level one (STM-I). The STM-I rate is an extension of the basic STS-I (for this reason also called STM-O) and operates at 155.52 Mbps, carrying three interleaved STS-l frames.***

Key Words: **SDH/SONET, STM 1 Frame, Payload, Pointer**.

1. Introduction

SONET/SDH defines the low level framing protocol used on these optical links. By "framing", we mean a block of bits (or octets) which have a structure, and which utilize some technique which allows us to find the boundaries of that frame structure. Parts of the block may be devoted to overhead for the network provider to use to manage the network. Other parts will be dedicated to carrying payload, or information we want to communicate. SDH is a multiplexed structure. Different containers (C-11, C-12, C-2, C-3 and C-4) with different rates are mapped to virtual containers (VC-11, VC-I2, VC-2, VC-3 and VC4). Pointers implement virtual container alignment, generating tributary units (TU-11, TU-l2, TU-2 and TU-3) or administrative units (AU-3 and AU-4). Tributary units are multiplexed in tributary unit groups (TUG-2 and TUG-3) according to container rate. TUG-2 can be multiplexed in VC-3 or TUG-3, and TUG-3 is multiplexed in VC-4. Administrative units are grouped in administrative unit group (AUG). Finally, AUG is multiplexed in one or more STM-ls. The frame is divided into three main sections: Payload Area, AU Pointer Area, and Section Overhead Area as: (see Fig. 1. STM-1 Frame structure)

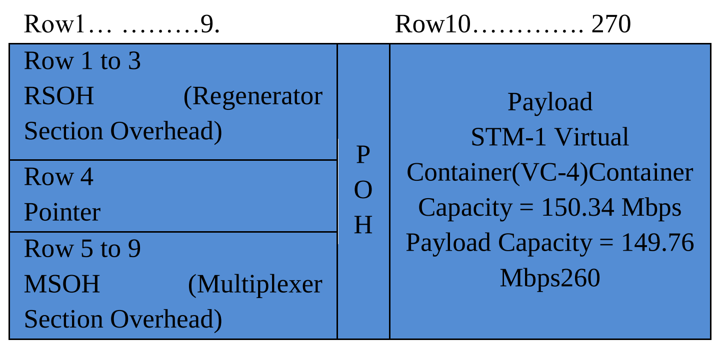

Fig. 1. STM-1 Frame structure

Each STM-l frame has 9 rows and 270 columns, and that it contains 9 columns of transport overhead, combining a pointer (AU-4 PTR) and section overhead (SOH).. If nothing were done, this would leave 261 columns for payload, including payload overhead. However, one form of the SDH payload, known as the virtual container 3 (VC-3) has a structure very similar to the STS-1, 87 columns by 9 rows of payload (see Fig. 1. STM-1 Frame structure). The first three VC-4 columns are VC-4 path overhead (POH) and two stuffing columns. Three interleaved TUG-3 are mapped in the remaining 258 columns of VC-4 (VC-4 payload). The VC-4 payload is composed by 6 stuffing columns and 63 interleaved TU12s. Each TU-12 is distributed along four columns, summing up a total of 36 bytes (9 bytes per column). The VC-12 virtual container preceded by a POH forms a TU-12. Therefore, each VC-12 is composed by an EI carrier plus two stuffing/control bytes. AU-4 PTR identifies the VC 4 start point. The VC-4 appears to start immediately after the section overhead part of the STM-1 frame. Actually, to facilitate efficient multiplexing and cross-connection of signals in the SDH network, VC-4

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structures are allowed to float within the payload part of STM-1 frames. This means that the VC-4 may begin anywhere within the STM-1 payload part. The result is that in most cases, a given VC-4 begins in one STM-1 frame and ends in the next. Were the VC-4 not allowed to float, buffers would be required to store the VC-4 data up to the instant it can be inserted in the STM-1 frame. These buffers (called slip buffers), which are often used in PDH multiplex equipment, introduce long delays. Moreover, they also cause disruptions in case a slip occurs .The STM-1 frame is the basic transmission format for SDH. The frame lasts for 125 microseconds; therefore there are 8000 frames per second.

The STM-1 signal frame comprises 9 rows by 270 columns, resulting in a total signal capacity of 2430 bytes (19440 bits per frame). Considering the STM-1 frame repetition rate, 8000 frames per second, this yields a bit rate of 155.520 Mbps. Each rate is an exact multiple of the lower rate therefore the hierarchy is synchronous.

2. SDH Section Overhead

In SDH networks, a transmission path can include three equipment functions:

- SDH terminal multiplexer: which performs the insertion/removal of tributary signals into SDH frames
- SDH cross-connect switch : permits to change the routing of tributary signals carried in SDH frames
- Regenerator: used to increase the physical range of the transmission path. See Fig. 2. STM-1 Frame SDH Section Overhead structure

Multiplexer section – A part of a transmission path located between a terminal multiplexer and an adjacent SDH cross-connect equipment, or between two adjacent SDH terminal multiplexers.

Regenerator section – A part of a transmission path located between a terminal multiplexer and SDH cross-connect equipment and the adjacent regenerator, or between two adjacent regenerators. A multiplexer section can include up to three regenerator sections.

Path – The logical connection between the point at which a tributary signal is assembled into its virtual container, and the point at which it is disassembled from the virtual container. To provide the support and maintenance signals associated with transmission across each segment, each of these segments is provided with its own overhead data, hence three types of overhead data:

Section overhead it is carried in the first nine columns of the STM-1 frame: Multiplexer section (MS) overhead – carried in overhead rows 5 to 9, Regenerator section (RS) overhead – carried in overhead rows 1 to 3, AU pointers– carried in overhead row 4.

Path overhead It is carried in the first column of a VC-4. The path overhead carried in the VC-4 is called high-order path overhead

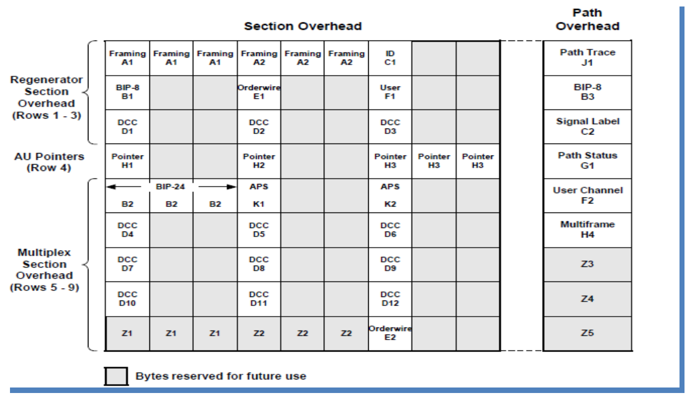

Fig. 2. STM-1 Frame SDH Section Overhead structure

2.1 Regenerator Section Overhead (RSOH)

A regenerator section of an SDH network comprises the transmission medium and associated equipment between a network element and the adjacent regenerator, or between two adjacent regenerators. The Regenerator Section Overhead contains only the information required for the elements located at both ends of a section. This might be two regenerators, a piece of line terminating equipment and a regenerator, or two pieces of line terminating equipment. The Regenerator Section Overhead is found in the first three rows of Columns 1 through 9 of the STM-1 frame. The functions of the various bytes carried in the STM-1 regenerator section overhead are described below.

Framing (A1, A2 Bytes):

The six framing bytes carry the framing pattern, and are used to indicate the start of an STM-1 frame.

Channel Identifier (C1 Byte):

The C1 byte is used to identify STM-1 frames within a higher-level SDH frame (STM-N, where the standardized values of N are 4, 16, etc.). The byte carries the binary representation of the STM-1 frame number in the STM-N frame.

Parity Check (B1 Byte) :

An 8-bit wide bit-interleaved parity (BIP-8) checksum is calculated over all the bits in the STM-1 frame, to permit error monitoring over the regenerator section. The computed even-

parity checksum is placed in the RSOH of the following STM-1 frame.

Data Communication Channel (D1, D2, D3 Bytes):
The 192 kbps Data Communication Channel (DCC) provides the capability to transfer network management and maintenance information between regenerator sections terminating equipment. .

User Communication Channel (F1 byte):
The F1 byte is intended to provide the network operator with a channel that is terminated at each regenerator location, and can carry proprietary communications. The information transmitted on this channel can be passed unmodified through a regenerator, or can be overwritten by data generated by the regenerator.

AU Pointers (H1, H2, H3 bytes):
The AU (Administration Unit) pointer bytes are used to enable the transfer of STM-1 frames within STM-N frames, and therefore are processed by multiplexer section terminating equipment. Separate pointers are provided for each STM-1 frame in an STM-N frame. AU pointer function is to link between the section overhead and the associated virtual container(s). Just like the H1, H2 pointer points to the SONET payload (SPE), the V1, V2 pointer points to the VT payload. The SONET equipment keeps track of where the V1, V2, V3, and V4 octets are so we can think of the VT payload as existing in isolation without the V1, V2, V3, V4 octets

2.2 Multiplexer Section Overhead (MSOH):

A multiplexer section of an SDH network comprises the transmission medium, together with the associated equipment (including regenerators) that provide the means of transporting information between two consecutive network nodes (e.g., SDH multiplexers). The Multiplex Section Overhead contains the information required between the multiplex section termination equipment at each end of the Multiplex section (that is, between consecutive network elements excluding the regenerators). The Multiplex Section Overhead is found in Rows 5 to 9 of Columns 1 through 9 of the STM-1 frame. The functions of the various bytes carried in the STM-1 multiplexer section overhead are described below.

Parity Check (B2 Bytes):
A 24-bit wide bit-interleaved parity (BIP) checksum is calculated over all the bits in the STM-1 frame (except those in the regenerator section overhead). The computed checksum is placed in the MSOH of the following STM-1 frame.

Data Communication Channel (D4 to D12 Bytes): Bytes D4 to D12 provide a 576 kbps data communication channel (DCC) between multiplexer section termination equipment. This channel is used to carry network administration and maintenance information.

VC-4 Path Overhead Functions:
The path overhead (POH) is contained within the virtual container portion of the STM-1 frame. The POH data of the VC-4 occupies all the 9 bytes of the first column. The functions of the various bytes carried in the VC-4 path overhead are described below.

Path Trace Message (J1 Byte):
The J1 byte is used to repetitively transmit a 64-byte string (message). The message is transmitted one byte per VC-4 frame.
A unique message is assigned to each path in an SDH network. Therefore, the path trace message can be used to check continuity between any location on a transmission path and the path source.

Parity Check (B3 Byte):
An 8-bit wide bit-interleaved parity even checksum, used for error performance monitoring on the path, is calculated over all the bits of the previous VC-4. The computed value is placed in the B3 byte.

Signal Label (C2 Byte):
The signal label byte, C2, indicates the structure of the VC-4 container. The signal label can assume 256 values; however two of these values are of particular importance:

• The all “0”s code represents the ***VC-4 unequipped*** state (i.e., the VC-4 does not carry any tributary signals)
• The code “00000001” represents the ***VC-4 equipped*** state.

Path Status (G1 Byte):
The G1 byte is used to send status and performance monitoring information from the receive side of the path terminating equipment to the path originating equipment. This allows the status and performance of a path to be monitored from either end, or at any point along the path.

Multiframe Indication (H4 byte):
The H4 byte is used as a payload Multiframe indicator, to provide support for complex payload structures, for example payload structures carrying multiple tributary units. If, for example, the TU overhead is distributed over four TU frames, these four frames form a TU Multiframe structure. The H4 byte then indicates which frame of the TU Multiframe is present in the current VC-4.

User Communication Channel (F2 Byte):
The F2 byte supports a user channel that enables proprietary network operator communications between path terminating equipment.

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Identifying VC-4 Beginning in the STM-1 Frame

When a VC-4 is assembled into the STM-1 frame, a pointer (byte) located in the section overhead of the STM-1 frame indicates the location of the first byte (J1) of the VC-4 that starts in that STM-1 frame.

3. Tributary Unit Types

TU-11: Each TU-11 frame consists of 27 bytes, structured as 3 columns of 9 bytes. At a frame rate of 8000 Hz, these bytes provide a transport capacity of 1.728 Mbps and will accommodate the mapping of a North American DS1 signal (1.544 Mbps). 84 TU-11s may be multiplexed into the STM-1 VC-4.

TU-12: Each TU-12 frame consists of 36 bytes, structured as 4 columns of 9 bytes. At a frame rate of 8000 Hz, these bytes provide a transport capacity of 2.304 Mbps and will accommodate the mapping of a CEPT 2.048 Mbps signal. 63 TU-12s may be multiplexed into the STM-1 VC-4.

TU-2: Each TU-2 frame consists of 108 bytes, structured as 12 columns of 9 bytes. At a frame rate of 8000 Hz, these bytes provide a transport capacity of 6.912 Mbps and will accommodate the mapping of a North American DS2 signal. 21 TU-2s may be multiplexed into the STM-1 VC-4.

TU-3: Each TU-3 frame consists of 774 bytes, structured as 86 columns of 9 bytes. At a frame rate of 8000 Hz, these bytes provide a transport capacity of 49.54 Mbps and will accommodate the mapping of a CEPT 34.368 Mbps signal or a North American 44.768 DS3 signal. Three TU-3s may be multiplexed into the STM-1 VC-4.

4.Results

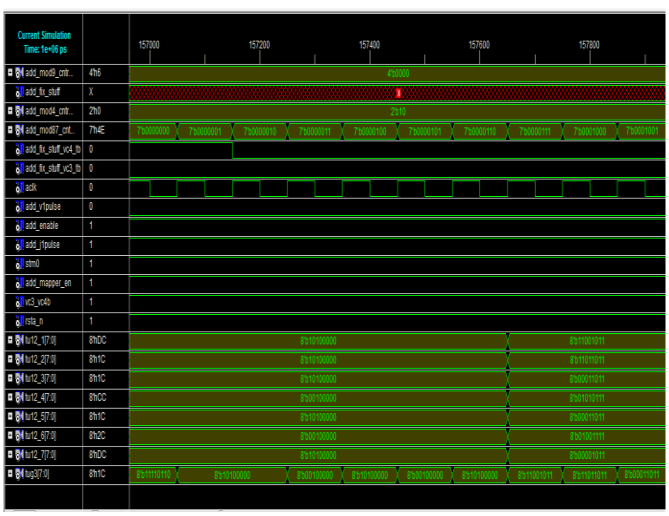

Fig 3 A1 octate Framing octets

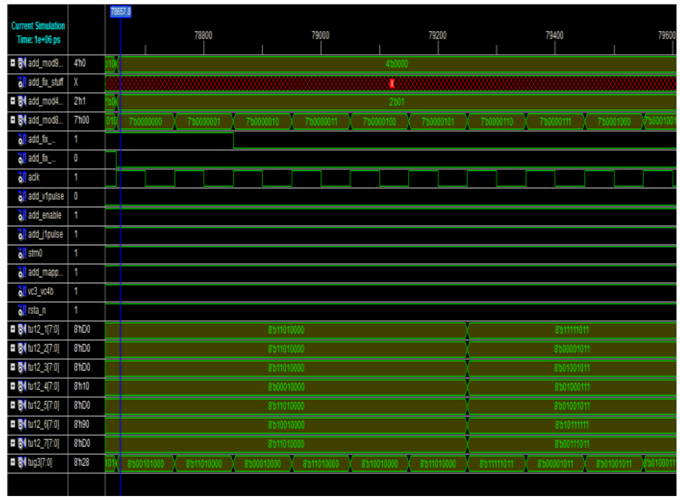

Fig 4 A2 octate Framing octets

The A1,A2 octets as shown in fig 3 and fig 4 allow the receiver to find the start of the SONET/SDH frame. The A1 octet is 1111 0110 (hex 0xf6)in previous figure while the A2 octet is 0010 1000 (hex 0x28). For SONET levels greater than STS-1 and less than or equal to STS-192, the A1 octet will be found in row one, columns 1 to N (where N is the SONET level). The A2 octet will be found in row one, columns N+1 to 2N. Framing for STS-768 uses the same A1, A2 values but limits the placement to columns 705 to 768 for A1 and columns 769 to 832 for A211. SDH uses the same values for the framing octets

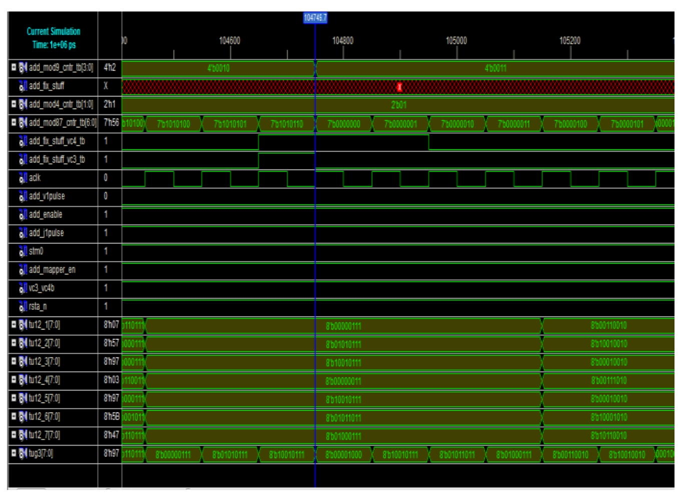

Fig 5 H2 pointer indication for justification

Suppose that data is coming into a device slower (or faster) than it is being transmitted out the other side. While buffers

can be used to mitigate the effect of different clocks, eventually something has to be done to adjust for the difference between the receive and transmit clocks. This is where the pointer and pointer action octets (H1, H2, H3) come in. The H1, H2 octets are the pointer octets, comprising 16 bits. The first four bits are the New Data Flag (NDF) bits and are set to 0110 during normal operation. We'll see that one way to introduce a new pointer value is by setting the new data flag and including the new pointer. The next two bits have no meaning in SONET but are used in SDH12. The last 10 bits are the actual pointer and can vary from 0 to 782. A value of zero indicates that the payload (the SPE) starts at the first octet after the H3 octet. If the payload started at the second octet after the H3 octet, the pointer would have a value of one, etc. See Figure 14 which shows the layout of the H1, H2 pointers. The numbers indicate the value that would be carried in the last 10 bits of the H1, H2 octets to point at that specific octet. For example, the H1, H2 pointer would contain zero to point to the octet after the H3 octet, and would contain 782 to point to the last octet in row 3 of the next frame. Another common pointer is to point to the first payload octet of the next frame, value 522.

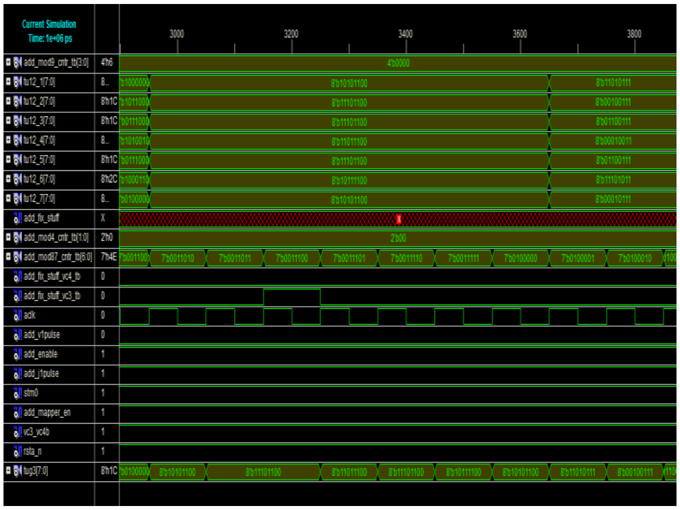

Fig 6 Multiplexing of tu12 indicates the vc3 first slot for fixed stuff byte

When the VC-3 is mapped into the AU-3, these columns are skipped. The fixed stuffing to bring all inputs to a common bit-rate ready for synchronous multiplexing. As the tributary signals are multiplexed and aligned, some spare capacity has been designed into the SDH frame to provide enough space for all the various tributary rates. Therefore, at certain points in the multiplexing hierarchy, this space capacity is filled with "fixed stuffing" bits that carry no information, but are required to fill up the particular frame. An SDH AU-3 and a Virtual Container level 3 (VC-3) which floats within the AU-3. Note that the VC-3 only has 85 columns while the AU-3 has 87. Two columns are fixed stuff.

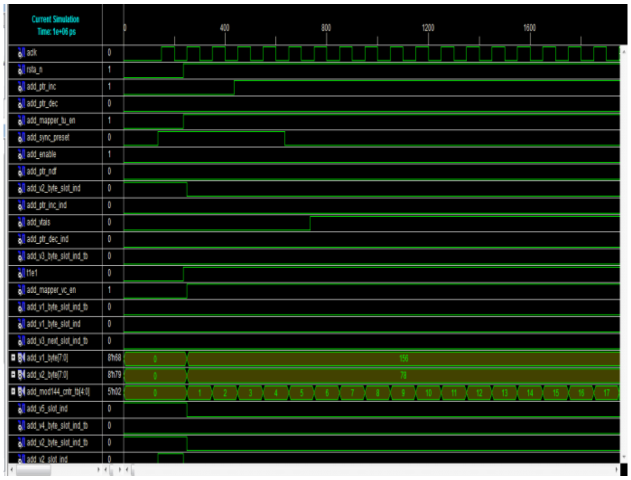

Fig 7 VT payload (TU-11/12) pointer offset value at the transmitter/add side.

This block generates v1v2 pointer. Also generates enable signals and test bus signal for VT payload (TU-11/12) pointers v1, v2, v3 and v4. The payload pointer indicates the offset between the VC payload and the STM-N frame by identifying the location of the first byte of the VC in the payload i.e. where the actual payload container starts.

5. Conclusion

STM1 frame is implemented through E1 path along with its different frequencies for its different path. The payload pointer indicates the offset between the VC payload and the STM-N frame by identifying the location of the first byte of the VC in the payload where the actual payload container starts. Enable signals and test bus signal for VT payload (TU-11/12) pointers v1, v2, v3 and v4 are generates. The BIP is calculated over the previous VC-12 frame including VC-12 path overheads but excludes V1, V2, and V3.

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